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Validity and reliability of 6-a-side small-sided game locomotor performance
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Abstract

In order to determine whether small-sided game (SSG) locomotor performance can serve as a fitness indicator, we (1) compared 6-a-side (6v6) SSG-intensity of players varying in fitness and skill, (2) examined the relationship of the 6v6-SSG and Yo-Yo IR2 and (3) assessed the reliability of the 6v6-SSG. Thirty-three professional senior, 30 professional youth, 62 amateur and 16 professional woman football players performed 4x7 minutes 6v6-SSGs recorded by a Local Position Measurement system. A substantial subgroup (N=113) also performed the Yo-Yo IR2. 47 Amateur players performed two or three 6v6-SSGs. No differences in 6v6-SSG time-motion variables were found between professional senior and professional youth players. Amateurs showed lower values than professional senior players on almost all time-motion variables ($ES=0.59-1.19$). Women displayed lower high-intensity time-motion variables than all other subgroups. Total distance run during 6v6-SSG was only moderately related to Yo-Yo IR2 distance ($r=0.45$), but estimated metabolic power, high speed ($>14.4 \text{ km}\cdot\text{h}^{-1}$), high acceleration ($>2 \text{ m}\cdot\text{s}^{-2}$), high power ($>20 \text{ W}\cdot\text{kg}^{-1}$) and very high ($35 \text{ W}\cdot\text{kg}^{-1}$) power showed higher correlations ($r=0.59-0.70$) with Yo-Yo IR2 distance. Intraclass correlation coefficient values were higher for total distance (0.84) than other time-motion variables (0.74–0.78). Although total distance and metabolic power during 6v6-SSG showed good reproducibility (coefficient of variation (CV) $<5\%$), CV was higher (8-14%) for all high-intensity time-motion variables. It was therefore concluded that standardised SSG locomotor performance can not serve be used as a valid and reliable fitness indicator for individual players.

Introduction

In football, and other team sports, small-sided games (SSGs) are widely used for aerobic and anaerobic conditioning. Compared to dedicated conditioning exercises, SSGs have the advantage to simultaneously train technical/tactical skills as well as sport-specific decision making (Davies, Young, Farrow, & Bahnert, 2013). With players' heart rates up to 90% of maximum heart rate, the intensity of play has been deemed high enough to promote aerobic endurance development (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011; Hoff, Wisloff, Engen, Kemi, & Helgerud, 2002; Stolen, Chamari, Castagna, & Wisloff, 2005). Next to aerobic endurance development, it has been suggested that SSGs may also provide a density training stimulus for (more anaerobic) acceleration abilities (Ade, Harley, & Bradley, 2014; Hodgson, Akenhead, & Thomas, 2014). Since SSGs are highly football specific and regularly performed throughout the competitive football season by professional teams, it would be of additional practical value if they could also be used to monitor the (changes in) fitness level of the players. This possibility will be investigated in the present study.

It has been suggested that a ceiling effect might limit highly fit and skilled players to achieve high-exercise intensities during SSGs (Hill-Haas et al., 2011; Hoff et al., 2002). If this were the case, then SSG locomotor performance, especially in the top teams, would provide limited information about the players' fitness level. However, to what extent fitness or skill level affects playing intensity of SSGs is unclear (Hill-Haas et al., 2011). Hoff et al. (2002) found that players with higher VO₂max showed a lower relative VO₂ in a 5-a-side SSG including goalkeepers. And Dellal et al. (2011a)

reported higher rate of perceived exertion (RPE) and blood lactate values, equal heart rate and less distance covered in high-intensity running and sprinting for amateur compared to professional players in 2- to 4-a-side SSGs without goalkeepers. These findings suggest that SSG locomotor performance might contain valuable information about player fitness.

Many factors influence SSG-intensity, including pitch size, game duration, presence of goalkeepers and coach encouragement (Halouani, Chtourou, Dellal, Chaouachi, & Chamari, 2014; Hill-Haas et al., 2011). Nevertheless, the variability of SSGs played in the same format has been found to be low for mean heart rate and total distance (coefficient of variation (CV) < 5%), especially in smaller SSG formats (Hill-Haas, Coutts, Rowsell, & Dawson, 2008; Rampinini et al., 2007b). At the same time, these studies report a larger variability for distance covered in high-speed categories (Hill-Haas et al., 2008; Rampinini et al., 2007b). Recently, it has been argued that, instead of total distance and distance covered in high-speed categories, metabolic power estimations and acceleration metrics could provide better and more valid information of (high-intensity) physical demands of SSGs and matches, and would therefore be worth exploring (Akenhead, Hayes, Thompson, & French, 2013; Gaudino et al., 2014b; Hodgson et al., 2014; Manzi, Impellizzeri, & Castagna, 2014). However, to date little information about the validity, variability and reliability of these new time-motion variables of SSGs in football is available. We therefore included these variables in the present study.

Throughout the season, coaches and practitioners seek information about their players' fitness level. Several test protocols are used to assess football-specific physical qualities, such as maximal (repeated) sprinting and aerobic and anaerobic endurance tests, e.g. the Yo-Yo tests (Krustrup et al., 2006). However, during the competitive season in professional settings maximal fitness tests are usually not employed (Halsen, 2014). Besides fitness tests, time-motion analysis of both matches and SSGs in training could perhaps provide additional information about football-specific fitness. Indeed, many studies found positive correlations between aerobic fitness tests and match locomotor performance assessed as (high intensity) distance covered (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009; Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010; Krustrup et al., 2003; Rampinini et al., 2007a; Rebelo, Brito, Seabra, Oliveira, & Krustrup, 2014) or estimated metabolic power (Manzi et al., 2014). However, in team sports, maximal (physical) performance is difficult to define during an actual match (Halsen, 2014), as it is influenced by many factors such as player position, score line, opposition and tactics (Carling, 2013). Unlike matches, SSGs can be better standardised, locomotor performance is less position dependent and there is more continuous play. In addition, tactics depend less on opposition and score line, compared to matches. Therefore, SSG locomotor performance could potentially provide more reliable indications of players' fitness level than actual match locomotor performance.

In order to determine whether small-sided game (SSG) locomotor performance can serve as a fitness indicator, we (1) compared 6-a-side (6v6)

SSG-intensity of players varying in fitness and skill, (2) examined the relationship of the 6v6-SSG and Yo-Yo Intermittent Recovery Level 2 Test (Yo-Yo IR2) and (3) assessed the reliability of the 6v6-SSG, including estimated metabolic power and acceleration metrics. We hypothesised that SSG locomotor performance would be higher in professionals compared to amateurs, in senior compared to youth and male compared to female top-level football players. Additionally, we expected there would be positive relations between distance completed during the Yo-Yo IR2 and time-motion variables measured during SSGs, in particular for estimated metabolic power as this accounts (partly) for the extra energy cost due to changes in velocity.

Methods

Participants

Measurements were performed on professional and amateur football players. All measurements of the professional teams were performed as a part of their regular training and testing programme and players approved the use of these data for the purpose of the present research. Professional teams, all from the same Dutch football club, were categorised as Prof Senior (first team playing in the highest national league and Champions League, and second team playing 2nd national league), Prof Youth (U19 and U17) and Women (BeNe League). Amateur players (playing at the highest, and the 5th and 6th Dutch amateur level) performed the same tests as the professional players and were informed about the experimental protocol

before providing their written consent. Participants' anthropometric characteristics are reported in Table 1. The study was approved by the Ethics Committee Human Movement Sciences of the Vrije Universiteit Amsterdam before it was conducted.

****Table 1 near here****

Procedures / Experimental design

6v6-SSG

All 6v6-SSG measurements were performed on a 'FIFA Two Stars' artificial turf pitch, except for the 6v6-SSG measurement of the first team, which was conducted on dry natural grass. A standardized 15-min warm-up and a 2 x 3 min passing exercise preceded a 4 x 7 min 6v6-SSG (including goalkeepers; pitch size = 40 x 34 m) with 2 min of passive rest between bouts. Coaches encouraged the players and demanded to keep pressure on the opponent at all times. Goalkeepers could be involved in the play without limit, but were restricted to a maximum of 3s of ball possession per occasion. When the ball was out of play, a foul was made or a goal was scored, the goalkeeper of the opponent team immediately continued the play with a new ball. The offside rule was not applied. Five minutes after the last bout of the SSG, perceived exertion scores (RPE; CR10) (Foster et al., 2001) were obtained from the players asking "How hard was the SSG?". Players were allowed to drink as much water as they liked both before and

during the 6v6-SSG. Players were all familiar with similar SSG formats from previous training sessions.

Yo-Yo IR2

The Yo-Yo IR2 is often used in football to evaluate the player's ability to perform intense intermittent exercise with high rates of aerobic and anaerobic energy turnover (Krustrup et al., 2006), i.e., physical qualities that are likely to be important during 6v6-SSGs. All Yo-Yo IR2 measurements were conducted on a 'FIFA Two Stars' artificial turf pitch. A standardised warm-up of 5 min of general running exercises and the first 2 min of the Yo-Yo IR1 test (Krustrup et al., 2003) preceded the Yo-Yo IR2 (Krustrup et al., 2006) until exhaustion. When the player failed to reach the finishing line on time twice, he or she was taken out of the test. The distance covered at the last run the player was still on time represented the test result. The same test leader took the test for all measurements. Heart rate was measured using the Polar Team² Pro System (Polar Electro Oy, Kempele, Finland).

Data inclusion

All 6v6-SSG and Yo-Yo IR2 measurements were conducted in the first half of the 2014-2015 season, at least 3 days after the match, and all in-season, except for the first team's (N=17) 6v6-SSG and Yo-Yo IR2 which were conducted 2 weeks before the start of the competitive season. Two players were excluded from the present study due to technical error of the transponder. For the comparison between teams, the first 6v6-SSG measurement of every player was included. Yo-Yo IR2 measurements were

paired to the 6v6-SSG measurement closest in time with a maximum of 16 days between 6v6-SSG and Yo-Yo IR2. In case of multiple data pairs (6v6-SSG and Yo-Yo IR2) per player only the first pair was included in the comparison. In order to test reliability of physiological and time-motion variables of the 6v6-SSG, three 6v6-SSG testing moments were organised for each amateur team within 3 weeks at the same day of the week. Due to unforeseen drop out of players (e.g. injuries), not all players could be tested three times. Players were included in the analysis if they participated in all three (27 players) or two (20 players) of the testing moments.

Time-motion measurement / Data collection

Players' physical activity of the 6v6-SSG was measured with a Local Position Measurement (LPM) system (version 05.91T; Inmotiotec GmbH, Regau, Austria). LPM data sampled at 24Hz or higher were filtered (integrated 'weighted Gaussian average' filter set at 85% as recommended by the manufacturer) using Inmotio software (version 3.4.1.86; Inmotiotec GmbH, Regau, Austria). The LPM system has been shown to provide acceptable measures of speed and mean acceleration and deceleration for intermittent activities (Stevens et al., 2014). Integrated metabolic power calculation, based on the equation of di Prampero et al. (2005) and extended by Osgnach, Poser, Bernardini, Rinaldo, and Di Prampero (2010) for use in team sports, was used to estimate metabolic power. Adjustable terrain factor (KT) and energy cost of constant running on flat terrain (in $\text{J}\cdot\text{kg}^{-1}\cdot\text{m}^{-1}$) were set at 1.1 and 4.0 respectively (Sassi et al., 2011; Stevens et al., 2015). Total

distance (m), average estimated metabolic power ($\text{W} \cdot \text{kg}^{-1}$) and distance (m) above $14.4 \text{ km} \cdot \text{h}^{-1}$ (high speed), $2 \text{ m} \cdot \text{s}^{-2}$ (high acceleration), $20 \text{ W} \cdot \text{kg}^{-1}$ (high power) and $35 \text{ W} \cdot \text{kg}^{-1}$ (very high power) were calculated. Arbitrary thresholds for high speed, high acceleration, high power and very high power are in accordance with previous studies (e.g. Gaudino, Alberti, & Iaia, 2014a), where high power is assumed to reflect mainly anaerobic activities (Manzi et al., 2014; Osgnach et al., 2010). Heart rate of 6v6-SSG was measured using LPM-integrated Polar Wearlink® technology (Polar Electro Oy, Kempele, Finland). The highest heart rate measured during the Yo-Yo IR2 tests, 6v6-SSGs or historical training sessions was designated as the player's maximum heart rate. Heart rate during 6v6-SSG was expressed as average absolute heart rate and average relative heart rate to player's maximum heart rate.

Statistics

To compare differences between subgroups a One-Way ANOVA was used, although homogeneity of variances as assessed with Levene's test was significant for high speed and high power, due to relatively low variance in the Women's team (Table 2). Bonferroni post hoc test was used to assess significant differences between subgroups. Effect sizes for post hoc pairwise comparisons were calculated with the pooled standard deviations and considered as small (> 0.2 – 0.6), moderate (> 0.6 – 1.2), large (> 1.2 – 2.0), very large (> 2.0 – 4.0) and extremely large (> 4.0) (Hopkins, Marshall, Batterham, & Hanin, 2009).

Pearson's correlation (r) was used to assess the association between Yo-Yo IR2 distance and selected 6v6-SSG variables. Magnitude of the correlation (r) was considered as trivial (< 0.1), small ($> 0.1-0.3$), moderate ($> 0.3-0.5$), large ($> 0.5-0.7$), very large ($> 0.7-0.9$), nearly perfect ($> 0.9-1.0$), and perfect (1.0), as defined by Hopkins (2000). Analyses were performed using IBM SPSS Statistics for Windows (Version 21.0).

Intraclass correlation coefficient (ICC), typical error (TE) and TE as a coefficient of variation (CV) of selected 6v6-SSG variables were calculated with the spreadsheet for the ICC provided by Hopkins (2011). Statistical significance was set at $p < .05$.

Results

Yo-Yo IR2 comparison between teams

One hundred and thirteen players performed a 6v6-SSG and the Yo-Yo IR2 (Table 1). Prof Senior (1300 ± 210 m) ran a greater Yo-Yo IR2 distance than Amateur (849 ± 264 m; ES = 1.81) and Women (634 ± 155 ; ES = 3.42). Although not significant, there was a moderate effect size (0.67) for distance between Prof Senior and Prof Youth (1147 ± 244 m).

6v6-SSG comparison between teams

The time-motion and physiological responses of the 6v6-SSG are shown in Table 2. There were no differences between Prof Senior and Prof Youth, except for relative heart rate, which was higher in Prof Youth (ES = 0.85). Total distance (ES = 0.59–0.64) and estimated metabolic power (ES = 0.68)

were lower for Amateur compared to both Prof Senior and Prof Youth. In addition, high speed (ES = 0.76), high power (ES = 1.19) and very high power (ES = 0.83) were lower for Amateur compared to Prof Senior. SSG total distance was not significantly different between Women and Prof Senior. However, the high speed (ES = 0.80–2.11), high acceleration (ES = 0.83–1.48) and very high power (ES = 1.13–2.39) of Women were lower compared to all other subgroups. Additionally, high power was lower for Women compared to Prof Senior (ES = 1.09). Although not significant, there was a moderate effect size for metabolic power between Women and Prof Senior (ES = 0.87) and between Women and Prof Youth (ES = 0.68). Finally, Women had higher RPE values (ES = 1.04–1.57) and higher relative heart rate values (ES = 1.10–1.81) compared to the other subgroups.

****Table 2 near here****

6v6-SSG vs Yo-Yo IR2

Table 3 shows the relations of 6v6-SSG time-motion and physiological variables with Yo-Yo IR2 distance. When all participants were pooled together, total distance showed only a moderate correlation with Yo-Yo IR2 distance, while all other 6v6-SSG time-motion variables showed larger correlations with Yo-Yo IR2 distance. Compared to the pooled values, within subgroup correlations with Yo-Yo IR2 distance were similar for total distance, estimated metabolic power and high power, but somewhat lower for high speed, high acceleration and very high power for some subgroups,

especially for the Women's team. Figure 1 illustrates the correlation between estimated metabolic power and Yo-Yo IR2 for all subgroups. When all participants are pooled together these data show that distance covered during Yo-Yo IR2 explained about one third of the variance in estimated metabolic power during the 6v6-SSGs.

****Table 3 near here****

****Figure 1 near here****

6v6-SSG Reliability

Table 4 indicates that ICC values were higher for total distance (0.84) than other time-motion variables (0.74–0.78). In addition, both total distance and metabolic power showed good reproducibility with CV's lower than 5%. As would be expected, CV was higher for the more specific time-motion variables.

****Table 4 near here****

Discussion

To evaluate the use of SSG locomotor performance as a possible indicator of physical fitness, we first compared 6v6-SSG locomotor performance, including estimated metabolic power and accelerations, of players with different fitness and skill levels. As expected, differences in—especially the

high intensity—6v6-SSG time-motion variables were found for Prof Senior compared to Amateur and Women; however, the effect sizes were much smaller than the effect sizes for the differences found in Yo-Yo IR2 distance for these subgroups. In addition, and not in agreement with our hypothesis, no differences in 6v6-SSG time-motion variables were found for Prof Senior compared to Prof Youth.

The similar 6v6-SSG time-motion values of Prof Senior and Prof Youth could be due to the fact that the Prof Youth players in our study were highly fit players as well, with a similar amount of training sessions and equal or just little less distance covered on the Yo-Yo IR2. However, the lower heart rate of Prof Senior compared to Prof Youth indicates there might have been a ceiling effect for exercise intensity for the Prof Senior (Hill-Haas et al., 2011). This suggestion is further illustrated by the high relative heart rate of the Women compared to Prof Senior. While it is possible that the maximum heart rate of the Women was somewhat underestimated (due to a relatively short Yo-Yo IR2 test duration and fewer monitored training sessions), their higher RPE score compared to other subgroups further supports this. Additionally, significant negative correlations were found for relative heart rate and RPE with Yo-Yo IR2 distance, meaning that players with lower distance in the Yo-Yo IR2 showed higher relative heart rate and RPE. Together these findings strongly suggest that a ceiling effect for exercise intensity was indeed present for (extremely) fit players.

In accordance with the results from our study, Dellal et al. (2011a) found lower total distance (~6%) and distance covered in high speed categories (~10%) during 2- to 4-a-side SSGs for amateur compared to professional

football players. The lower distance at high speed ($>14.4 \text{ km}\cdot\text{h}^{-1}$) in both Amateur (-16%) and Women (-33%) compared to Prof Senior in the present study is most likely due to a lower maximum (aerobic) speed of Amateur and Women players. Furthermore, RPE scores in our study (mean range = 5.3-7.6) were equal or somewhat lower than usually reported in similar or smaller-sided games (Casamichana & Castellano, 2010; Dellal et al., 2011a; Dellal, Lago-Penas, Wong del, & Chamari, 2011b; Koklu, Ersoz, Alemdaroglu, Asc, & Ozkan, 2012; Rampinini et al., 2007b). One reason could be that in those previous studies RPE scores were taken immediately after the SSG, while we took RPE scores 5 min after the end of the SSG to increase the likelihood that players reported the RPE of all four bouts of the SSG together rather than for the last bout only.

By studying metabolic power, we strived to include one sensitive measure that would account for all locomotor activities of the SSG, including accelerations and decelerations. The present results indicate that we succeeded in this, at least in part. The estimated metabolic power ($11.9 \text{ W}\cdot\text{kg}^{-1}$) for Prof Senior players (partly) accounted for the extra energy cost needed for accelerations and decelerations and was around 30% higher compared to when speed would be assumed constant ($9.2 \text{ W}\cdot\text{kg}^{-1}$ at the average speed of $7.5 \text{ km}\cdot\text{h}^{-1}$) as would be the case when using total distance to estimate metabolic costs. Most likely, the 30% additional cost represents an underestimation of the true difference, because calculated metabolic power still underestimates the true metabolic power, with the amount of underestimation depending on the tracking technique and exercise mode (Stevens et al., 2015). Even though metabolic power is still underestimated,

estimated metabolic power can potentially discriminate better between true differences in locomotor performance compared to total distance covered. For example, the effect size between Prof Senior and Women was higher for estimated metabolic power ($ES = 0.87$) than total distance ($ES = 0.13$). Also, Yo-Yo IR2 distance correlated slightly better to estimated metabolic power during 6v6-SSG ($r = 0.60$) compared to 6v6-SSG total distance covered ($r = 0.45$), both overall and within most subgroups. However, although the metabolic approach is interesting, its limitations should be acknowledged (Di Prampero et al., 2005). Recently, metabolic power showed poor reliability when used in combination with low-sampled GPS time-motion data (Buchheit, Manouvrier, Cassirame, & Morin, in press). Therefore, although for some purposes it may complement more traditional time-motion variables, care should be taken when interpreting metabolic power estimations. In the present study metabolic power metrics did not provide much incremental validity over total distance or distance at high speed or high acceleration.

To the best of our knowledge, the present study is the first to determine the relation between locomotor performances during a standardised SSG with performance on a frequently used fitness endurance test in football. In line with our expectations, positive relations were found between Yo-Yo IR2 distance and 6v6-SSG time-motion variables. As regards the high-intensity variables, high power had the most consistent correlation with Yo-Yo IR2 distance within subgroups, especially for Prof Senior, Prof Youth and Amateur. Nevertheless, most of the correlations found were only moderate. Additionally, the lower correlations for the Women subgroup on some time-

motion variables could be due to the high intensity of the Yo-Yo IR2, which may have made the test less reliable for this specific subgroup.

Although no other studies related aerobic or anaerobic endurance tests to SSG locomotor performance, previous studies (Buchheit et al., 2010; Castagna et al., 2009; Castagna et al., 2010; Krstrup et al., 2003; Rampinini et al., 2007a; Rebelo et al., 2014) found similar positive correlations between aerobic fitness tests and match locomotor performance (total distance and distance in high speed categories) as we found between Yo-Yo IR2 distance and SSG locomotor performance. Moreover, Manzi et al. (2014) found moderate to large correlations (0.52-0.83) between several aerobic fitness variables (e.g. $\text{VO}_{2\text{max}}$, $\text{VO}_{2\text{VT}}$ and maximal aerobic speed) and distance covered in high-power categories ($> 20 \text{ W}\cdot\text{kg}^{-1}$, $> 35 \text{ W}\cdot\text{kg}^{-1}$, $> 55 \text{ W}\cdot\text{kg}^{-1}$) during matches.

The present study assessed the variability and test-retest reliability of the 6v6-SSG for commonly used time-motion variables, including estimated metabolic power and acceleration metrics. Variability was low for total distance and metabolic power (both 4%), but higher for distance covered above high-intensity thresholds for speed, acceleration and metabolic power (8-14%). The low variability for total distance and (relative) heart rate (2%), but higher variability for high speed and RPE (30%), is in agreement with previous studies investigating 6-a-side SSGs without goalkeepers (Hill-Haas et al., 2008; Rampinini et al., 2007b).

Although locomotor performance in the standardised 6v6-SSG investigated in our study differed between Prof Senior and Amateur and between Prof

Senior and Women on several time-motion variables, the differences were relatively small compared to the differences among subgroups in Yo-Yo IR2 performance. The latter finding suggests that fitness level varied among our subgroups. Although SSGs are better standardised than matches (e.g. continuous play, less position dependent), they still have some limitations that may explain the lack of differentiation in 6v6-SSG locomotor performance between subgroups, the only moderate correlation to Yo-Yo IR2 and the relatively low reliability. First, despite instructions to keep pressure on the ball at all times, it depends on the player's motivation if he or she does so. However, also in other fitness tests such as the Yo-Yo IR2 motivation plays an important role. Second, there is the possibility of a ceiling effect for achieving a high-exercise intensity for fitter and more skilled players (Hill-Haas et al., 2011), which seemed to be confirmed by the present results that showed women had higher RPE and heart rate values compared to Prof Senior. Perhaps, a larger pitch size or less players on the same pitch could increase the physical demands (Hill-Haas et al., 2011), especially for the professional players. However, it is not clear whether this would increase differentiation in locomotor performance between subgroups or players and/or increase the correlation with the Yo-Yo IR2 performance. Third, although we tried to minimise tactical influence through standardisation of the SSG and a focus on keeping a high pace, most likely tactical elements will still influence locomotor performance.

We have found indications that players' motivation and/or play development in SSGs influenced locomotor performance as well as the physiological load of individual players. When compared for the first and

second 6v6-SSG measurement of individual amateur players ($N = 45$) there was a significant moderate correlation between delta heart rate and delta total distance ($r = 0.37$) as well as between delta heart rate and delta metabolic power ($r = 0.38$). Therefore, in practice, providing that maximal heart rates of individual players are well established, inclusion of heart rate (internal load) when interpreting time-motion variables (external load) of SSGs may possibly aid in detecting less fit players or changes in fitness of individual players across the season (Akubat, Barrett, & Abt, 2014).

The advantage of SSGs is that they are frequently used during regular training in the competitive season. As such, multiple SSGs can perhaps be used to objectively signalise possible limitations in physical endurance capacities of individual players. When in doubt, additional maximal fitness endurance tests can be conducted for the selected player(s), without having to test all players. Moreover, younger players might need to compensate in work rate when playing with older players because of a likely lower skill and less developed physique. Therefore, for youth players SSG monitoring can perhaps aid in determining if players are physically capable to join a higher team with fitter and better skilled players. Nevertheless, as the reliability and validity of SSG locomotor performance is relatively low, SSGs cannot replace standardised tests that assess physical endurance capacities. Although ecological validity of football-specific SSGs is higher than for standard fitness tests, it is not perfect and in particular the number of high speed runs is lower compared to real matches.

Conclusions

The overall aim of this study was to determine whether the use of 6v6-SSG locomotor performance can serve as a fitness indicator. To this end, we (1) compared 6-a-side (6v6) SSG-intensity of players varying in fitness and skill, (2) examined the relationship of the 6v6-SSG and Yo-Yo IR2 and (3) assessed the reliability of the 6v6-SSG. In particular the high-intensity 6v6-SSG time-motion variables were higher for Prof Senior compared to Amateur (moderate effect sizes) and Women (large to very large effect sizes); however, no differences were present in 6v6-SSG time-motion variables between Prof Senior and Prof Youth. We found evidence of a ceiling effect for exercise intensity during SSGs for fit players. Yo-Yo IR2 distance correlated only moderately to 6v6-SSG total distance and highly to other time-motion variables. Total distance and estimated metabolic power showed good reproducibility, albeit lower for the high-intensity variables. Test-retest reliability was reasonable for distance, but relatively low for all other variables. Altogether, we conclude that standardised (medium sized) SSGs locomotor performance alone can not be used as a valid and reliable fitness indicator for individual players.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

- Ade, J. D., Harley, J. A., & Bradley, P. S. (2014). Physiological response, time-motion characteristics, and reproducibility of various speed-endurance drills in elite youth soccer players: small-sided games versus generic running. *International Journal of Sports Physiology & Performance*, 9(3), 471-479.
- Akenhead, R., Hayes, P. R., Thompson, K. G., & French, D. (2013). Diminutions of acceleration and deceleration output during professional football match play. *Journal of Science and Medicine in Sport*, 16(6), 556-561.
- Akubat, I., Barrett, S., & Abt, G. (2014). Integrating the internal and external training loads in soccer. *International Journal of Sports Physiology & Performance*, 9(3), 457-462.
- Buchheit, M., Manouvrier, C., Cassirame, J., & Morin, J. B. (in press). Monitoring locomotor load in soccer: is metabolic power, powerful? *International Journal of Sports Medicine*.
- Buchheit, M., Mendez-Villanueva, A., Simpson, B. M., & Bourdon, P. C. (2010). Match running performance and fitness in youth soccer. *International Journal of Sports Medicine*, 31(11), 818-825.
- Carling, C. (2013). Interpreting physical performance in professional soccer match-play: should we be more pragmatic in our approach? *Sports Medicine*, 43(8), 655-663.
- Casamichana, D., & Castellano, J. (2010). Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: effects of pitch size. *Journal of Sports Sciences*, 28(14), 1615-1623.
- Castagna, C., Impellizzeri, F., Cecchini, E., Rampinini, E., & Alvarez, J. C. (2009). Effects of intermittent-endurance fitness on match performance in young male soccer players. *Journal of Strength and Conditioning Research*, 23(7), 1954-1959.
- Castagna, C., Manzi, V., Impellizzeri, F., Weston, M., & Barbero Alvarez, J. C. (2010). Relationship between endurance field tests and match performance in young soccer players. *Journal of Strength and Conditioning Research*, 24(12), 3227-3233.
- Davies, M. J., Young, W., Farrow, D., & Bahnert, A. (2013). Comparison of agility demands of small-sided games in elite Australian football. *International Journal of Sports Physiology & Performance*, 8(2), 139-147.
- Dellal, A., Hill-Haas, S., Lago-Penas, C., & Chamari, K. (2011a). Small-sided games in soccer: amateur vs. professional players' physiological responses, physical, and technical activities. *Journal of Strength and Conditioning Research*, 25(9), 2371-2381.
- Dellal, A., Lago-Penas, C., Wong del, P., & Chamari, K. (2011b). Effect of the number of ball contacts within bouts of 4 vs. 4 small-sided soccer games. *International Journal of Sports Physiology & Performance*, 6(3), 322-333.

- Di Prampero, P. E., Fusi, S., Sepulcri, L., Morin, J. B., Belli, A., & Antonutto, G. (2005). Sprint running: a new energetic approach. *Journal of Experimental Biology*, 208(14), 2809-2816.
- Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, 15(1), 109-115.
- Gaudino, P., Alberti, G., & Iaia, F. M. (2014a). Estimated metabolic and mechanical demands during different small-sided games in elite soccer players. *Human Movement Science*, 36, 123-133.
- Gaudino, P., Iaia, F. M., Alberti, G., Hawkins, R. D., Strudwick, A. J., & Gregson, W. (2014b). Systematic bias between running speed and metabolic power data in elite soccer players: influence of drill type. *International Journal of Sports Medicine*, 35(6), 489-493.
- Halouani, J., Chtourou, H., Dellal, A., Chaouachi, A., & Chamari, K. (2014). Physiological responses according to rules changes during 3 vs. 3 small-sided games in youth soccer players: stop-ball vs. small-goals rules. *Journal of Sports Sciences*, 32(15), 1485-1490.
- Halsen, S. L. (2014). Monitoring training load to understand fatigue in athletes. *Sports Medicine*, 44(Suppl 2), 139-147.
- Hill-Haas, S., Coutts, A., Rowsell, G., & Dawson, B. (2008). Variability of acute physiological responses and performance profiles of youth soccer players in small-sided games. *Journal of Science and Medicine in Sport*, 11(5), 487-490.
- Hill-Haas, S. V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of small-sided games training in football: a systematic review. *Sports Medicine*, 41(3), 199-220.
- Hodgson, C., Akenhead, R., & Thomas, K. (2014). Time-motion analysis of acceleration demands of 4v4 small-sided soccer games played on different pitch sizes. *Human Movement Science*, 33, 25-32.
- Hoff, J., Wisloff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine*, 36(3), 218-221.
- Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Medicine*, 30(1), 1-15.
- Hopkins, W. G. (2011). Precision of measurement. In: A New View of Statistics (newstats.org/precision.html).
- Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, 41(1), 3-13.
- Koklu, Y., Ersoz, G., Alemdaroglu, U., Asc, A., & Ozkan, A. (2012). Physiological responses and time-motion characteristics of 4-a-side small-sided game in young soccer players: the influence of different team formation methods. *Journal of Strength and Conditioning Research*, 26(11), 3118-3123.
- Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine & Science in Sports & Exercise*, 35(4), 697-705.
- Krustrup, P., Mohr, M., Nybo, L., Jensen, J. M., Nielsen, J. J., & Bangsbo, J. (2006). The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. *Medicine & Science in Sports & Exercise*, 38(9), 1666-1673.

- Manzi, V., Impellizzeri, F., & Castagna, C. (2014). Aerobic fitness ecological validity in elite soccer players: a metabolic power approach. *Journal of Strength and Conditioning Research*, 28(4), 914-919.
- Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: a new match analysis approach. *Medicine & Science in Sports & Exercise*, 42(1), 170-178.
- Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. M. (2007a). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine*, 28(3), 228-235.
- Rampinini, E., Impellizzeri, F. M., Castagna, C., Abt, G., Chamari, K., Sassi, A., & Marcora, S. M. (2007b). Factors influencing physiological responses to small-sided soccer games. *Journal of Sports Sciences*, 25(6), 659-666.
- Rebello, A., Brito, J., Seabra, A., Oliveira, J., & Krstrup, P. (2014). Physical match performance of youth football players in relation to physical capacity. *European Journal of Sport Science*, 14 Suppl 1, S148-156.
- Sassi, A., Stefanescu, A., Menaspa, P., Bosio, A., Riggio, M., & Rampinini, E. (2011). The cost of running on natural grass and artificial turf surfaces. *Journal of Strength and Conditioning Research*, 25(3), 606-611.
- Stevens, T. G. A., de Ruiter, C. J., van Maurik, D., van Lierop, C. J., Savelsbergh, G. J. P., & Beek, P. J. (2015). Measured and estimated energy cost of constant and shuttle running in soccer players. *Medicine & Science in Sports & Exercise*, 47(6), 1219-1224.
- Stevens, T. G. A., de Ruiter, C. J., van Niel, C., van de Rhee, R., Beek, P. J., & Savelsbergh, G. J. P. (2014). Measuring acceleration and deceleration in soccer-specific movements using a Local Position Measurement (LPM) system. *International Journal of Sports Physiology & Performance*, 9(3), 446-456.
- Stolen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer: an update. *Sports Medicine*, 35(6), 501-536.

Table 1. Weekly field training sessions, anthropometric characteristics and number of participants per study for all subgroups (mean \pm SD).

| | Weekly field sessions* | 6v6-SSG comparison between subgroups | | | | 6v6-SSG vs Yo-Yo IR2 | | 6v6-SSG reliability |
|-------------|------------------------|--------------------------------------|-------------|-------------|-------------|----------------------|------------------------|---------------------|
| | | N | Age (years) | Height (cm) | Weight (kg) | N** | Yo-Yo IR2 distance (m) | N |
| Prof Senior | 5 | 33 | 21 \pm 3 | 181 \pm 6 | 76 \pm 7 | 26 | 1300 \pm 210 | 47 |
| Prof Youth | 4 | 30 | 17 \pm 1 | 176 \pm 6 | 68 \pm 7 | 19 | 1147 \pm 244 | |
| Amateur | 2-3 | 62 | 26 \pm 4 | 182 \pm 8 | 79 \pm 9 | 52 | 849 \pm 264 | |
| Women | 5 | 16 | 24 \pm 4 | 171 \pm 6 | 64 \pm 4 | 16 | 634 \pm 155 | |

Notes: * Excluding matches. ** Note that from the participants whose 6v6-SSG data were analysed a substantial subgroup also performed the Yo-Yo Intermittent Recovery Level 2 (Yo-Yo IR2) test.

Table 2. Time-motion variables and physiological responses of the 6-a-side small-sided game for different subgroups (Mean \pm SD).

| | Prof Senior (N=33) | Prof Youth (N=30) | Amateur (N=62) | Women (N=16) | ANOVA p-value |
|--------------------------|-------------------------------|-------------------------------|---------------------------------|---------------------------------|------------------|
| TD (m) | 3501 \pm 204 ^b | 3525 \pm 250 ^b | 3338 \pm 308 ^{c,d} | 3474 \pm 240 | .004 |
| MP (W·kg ⁻¹) | 11.85 \pm 0.76 ^b | 11.87 \pm 0.85 ^b | 11.18 \pm 1.09 ^{c,d} | 11.18 \pm 0.76 | .001 |
| HS (m) | 693 \pm 121 ^{a,b} | 657 \pm 140 ^a | 579 \pm 161 ^{a,d} | 461 \pm 76 ^{b,c,d} | .000 |
| HA (m) | 304 \pm 41 ^a | 296 \pm 35 ^a | 282 \pm 46 ^a | 245 \pm 35 ^{b,c,d} | .000 |
| HP (m) | 832 \pm 112 ^{a,b} | 822 \pm 117 | 758 \pm 150 ^d | 716 \pm 89 ^d | .003 |
| VHP (m) | 328 \pm 53 ^{a,b} | 301 \pm 49 ^a | 277 \pm 64 ^{a,d} | 210 \pm 38 ^{b,c,d} | .000 |
| HR (bpm) | 171 \pm 7 ^c | 180 \pm 9 ^{b,d} | 173 \pm 11 ^c | 177 \pm 7 | .002 |
| HR (%max) | 87.7 \pm 3.3 ^{a,c} | 90.4 \pm 2.8 ^{a,d} | 89.3 \pm 3.7 ^a | 93.3 \pm 2.4 ^{b,c,d} | .000 |
| RPE (CR10) | 5.3 \pm 1.3 ^a | 5.9 \pm 1.4 ^a | 5.8 \pm 1.8 ^a | 7.6 \pm 1.5 ^{b,c,d} | .000 |

Notes: ^a = different from Women; ^b = different from Amateur; ^c = different from Prof Youth; ^d = different from Prof Senior; TD = total distance; MP = estimated metabolic power; HS = high speed (> 14.4 km·h⁻¹); HA = high acceleration (> 2 m·s⁻²); HP = high power (> 20 W·kg⁻¹); VHP = very high power (> 35 W·kg⁻¹); HR = heart rate (average); RPE = rate of perceived exertion. Note that for heart rate variables the number of players (N) is 31, 28, 61 and 16 respectively.

Table 3. Pearson's correlation (r) of time-motion variables and physiological responses of the 6-a-side small-sided game with Yo-Yo IR2 distance for all participants pooled together and per subgroup.

| | All (N=113) | | | Prof Senior (N=26) | Prof Youth (N=19) | Amateur (N=52) | Women (N=16) |
|--------------------------|-------------|------------------|-----------|-----------------------|----------------------|-------------------|-----------------|
| | r | 90% CI | Magnitude | r | r | r | r |
| TD (m) | 0.45*** | (0.31–0.56) | moderate | 0.59** | 0.44 | 0.48*** | 0.43 |
| MP (W·kg ⁻¹) | 0.60*** | (0.49–0.69) | large | 0.59** | 0.48* | 0.57*** | 0.63** |
| HS (m) | 0.70*** | (0.61–0.77) | large | 0.51** | 0.58** | 0.63*** | 0.26 |
| HA (m) | 0.59*** | (0.48–0.68) | large | 0.32 | 0.49* | 0.55*** | 0.67** |
| HP (m) | 0.63*** | (0.53–0.72) | large | 0.60** | 0.62** | 0.62*** | 0.48 |
| VHP (m) | 0.70*** | (0.61–0.77) | large | 0.41* | 0.60** | 0.63*** | 0.28 |
| HR (% max) | -0.35** | (-0.48 to -0.21) | moderate | 0.00 | -0.14 | -0.30* | -0.05 |
| RPE (CR10) | -0.29** | (-0.43 to -0.15) | small | -0.07 | -0.06 | -0.27 | -0.12 |

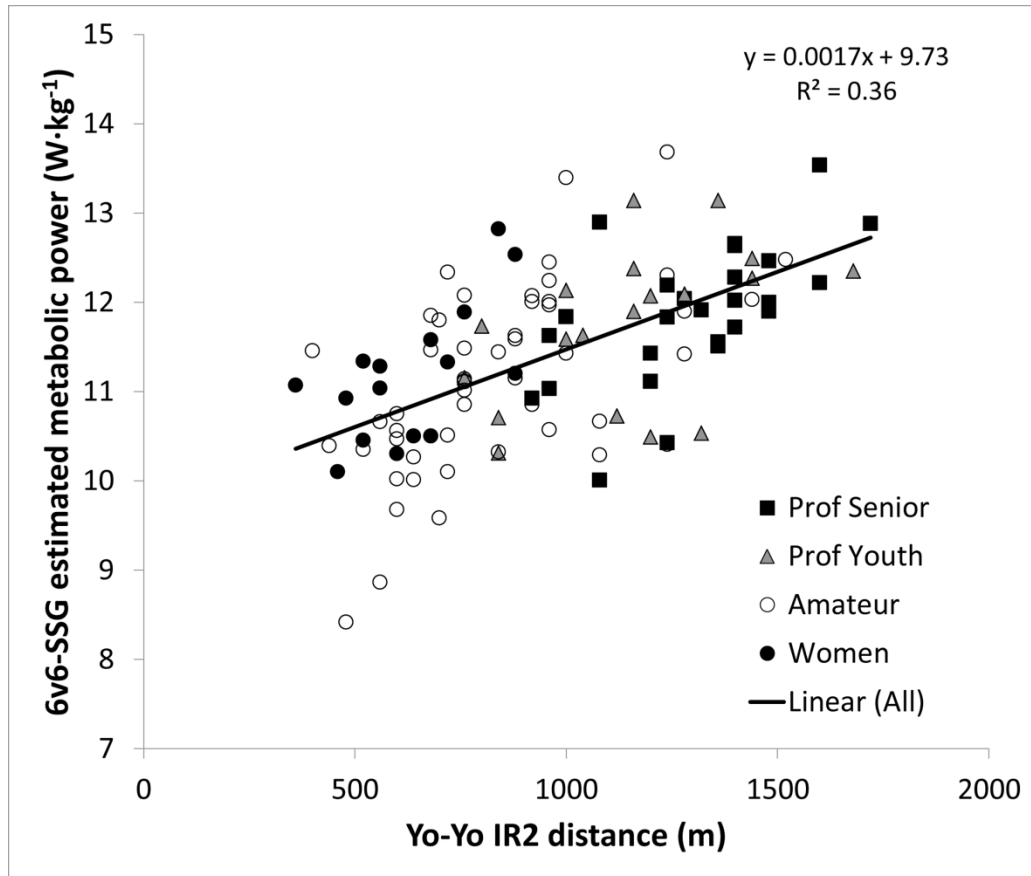
Notes: * = $P < .05$; ** = $P < .01$; *** = $P < .001$; CI = confidence interval; TD = total distance; MP = estimated metabolic power; HS = high speed ($> 14.4 \text{ km}\cdot\text{h}^{-1}$); HA = high acceleration ($> 2 \text{ m}\cdot\text{s}^{-2}$); HP = high power ($> 20 \text{ W}\cdot\text{kg}^{-1}$); VHP = very high power ($> 35 \text{ W}\cdot\text{kg}^{-1}$); HR = heart rate (average); RPE = rate of perceived exertion. Note that for heart rate variables the number of players (N) is 25, 19, 50 and 16 respectively.

Table 4. Intraclass correlation coefficient (ICC), typical error (TE) and TE as a coefficient of variation (CV) of 6-a-side small-sided game time-motion and physiological variables.

| | ICC (90% CI) | TE (90% CI) | TE as CV (%; 90% CI) |
|--------------------------------------|------------------|------------------|----------------------|
| TD (m) | 0.84 (0.76–0.89) | 119 (103–141) | 3.5 (3.0–4.1) |
| MP ($\text{W}\cdot\text{kg}^{-1}$) | 0.78 (0.68–0.86) | 0.49 (0.43–0.58) | 4.4 (3.8–5.2) |
| HS (m) | 0.74 (0.62–0.83) | 81.6 (71.2–96.8) | 13.9 (12.0–16.7) |
| HA (m) | 0.74 (0.63–0.83) | 23.1 (20.2–27.5) | 8.4 (7.3–10.0) |
| HP (m) | 0.75 (0.63–0.83) | 70.4 (61.4–83.5) | 9.4 (8.1–11.2) |
| VHP (m) | 0.77 (0.66–0.85) | 30.1 (26.2–35.7) | 11.1 (9.6–13.3) |
| HR (bpm) | 0.85 (0.77–0.90) | 3.74 (3.27–4.48) | 2.2 (1.9–2.7) |
| HR (%max) | 0.61 (0.45–0.74) | 1.94 (1.70–2.33) | 2.2 (1.9–2.7) |
| RPE (CR10) | 0.37 (0.18–0.55) | 1.40 (1.22–1.65) | 29.7 (25.5–36.2) |

CI = confidence interval; TD = total distance; MP = estimated metabolic power; HS = high speed ($> 14.4 \text{ km}\cdot\text{h}^{-1}$); HA = high acceleration ($> 2 \text{ m}\cdot\text{s}^{-1}$); HP = high power ($> 20 \text{ W}\cdot\text{kg}^{-1}$); VHP = very high power ($> 35 \text{ W}\cdot\text{kg}^{-1}$); HR = heart rate (average); RPE = rate of perceived exertion.

Figure 1. Scatter-Plot of 6-a-side (6v6) small-sided game (SSG) estimated metabolic power and Yo-Yo Intermittent Recovery Level 2 (IR2) distance and per subgroup.



Note: The y-axis does not start on zero. Displayed linear regression equation is for all participants pooled together.